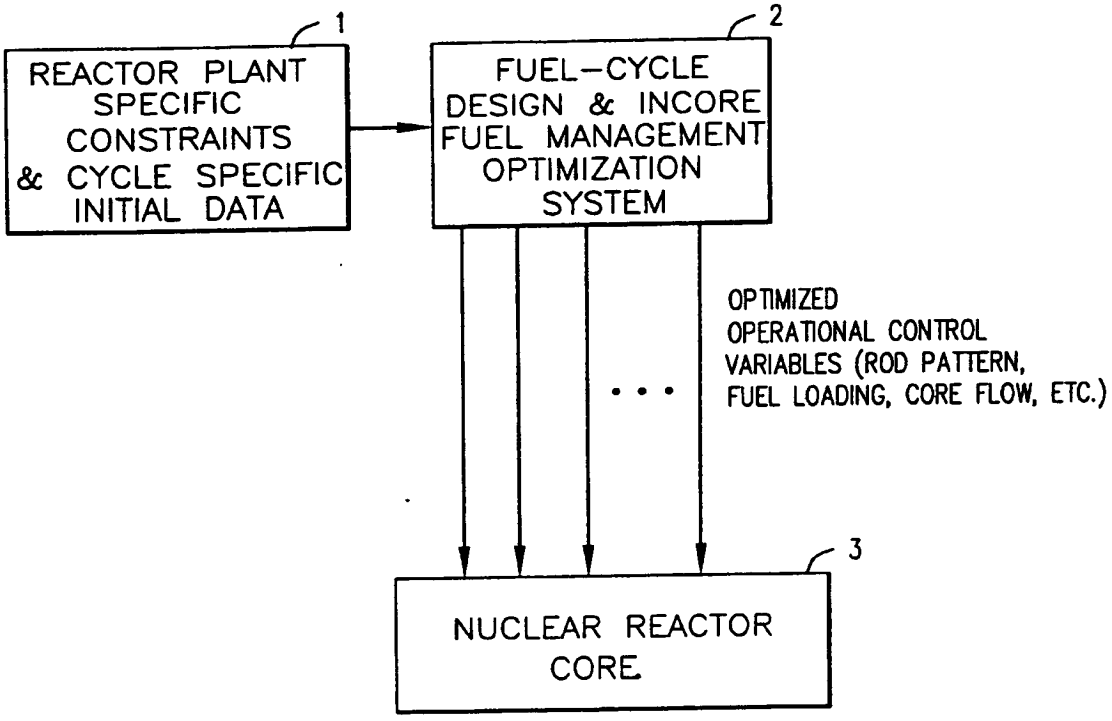

1
REACTOR PLANT SPECIFIC CONSTRAINTS & CYCLE SPECIFIC INITIAL DATA
2
FUEL-CYCLE DESIGN & INCORE FUEL MANAGEMENT OPTIMIZATION SYSTEM
OPTIMIZED OPERATIONAL CONTROL VARIABLES (ROD PATTERN, FUEL LOADING, CORE FLOW, ETC.)
3
NUCLEAR REACTOR CORE

Fig.1A

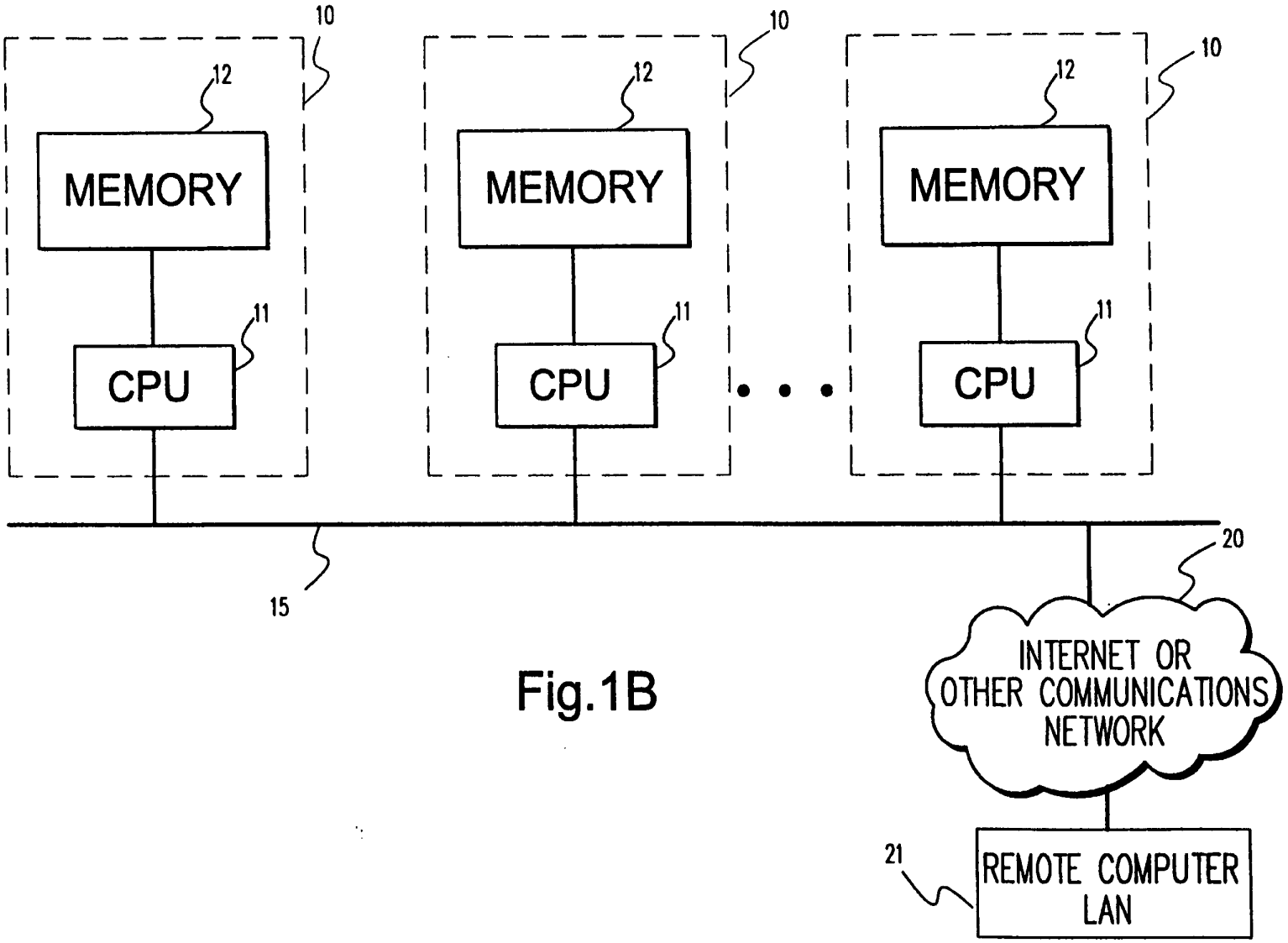
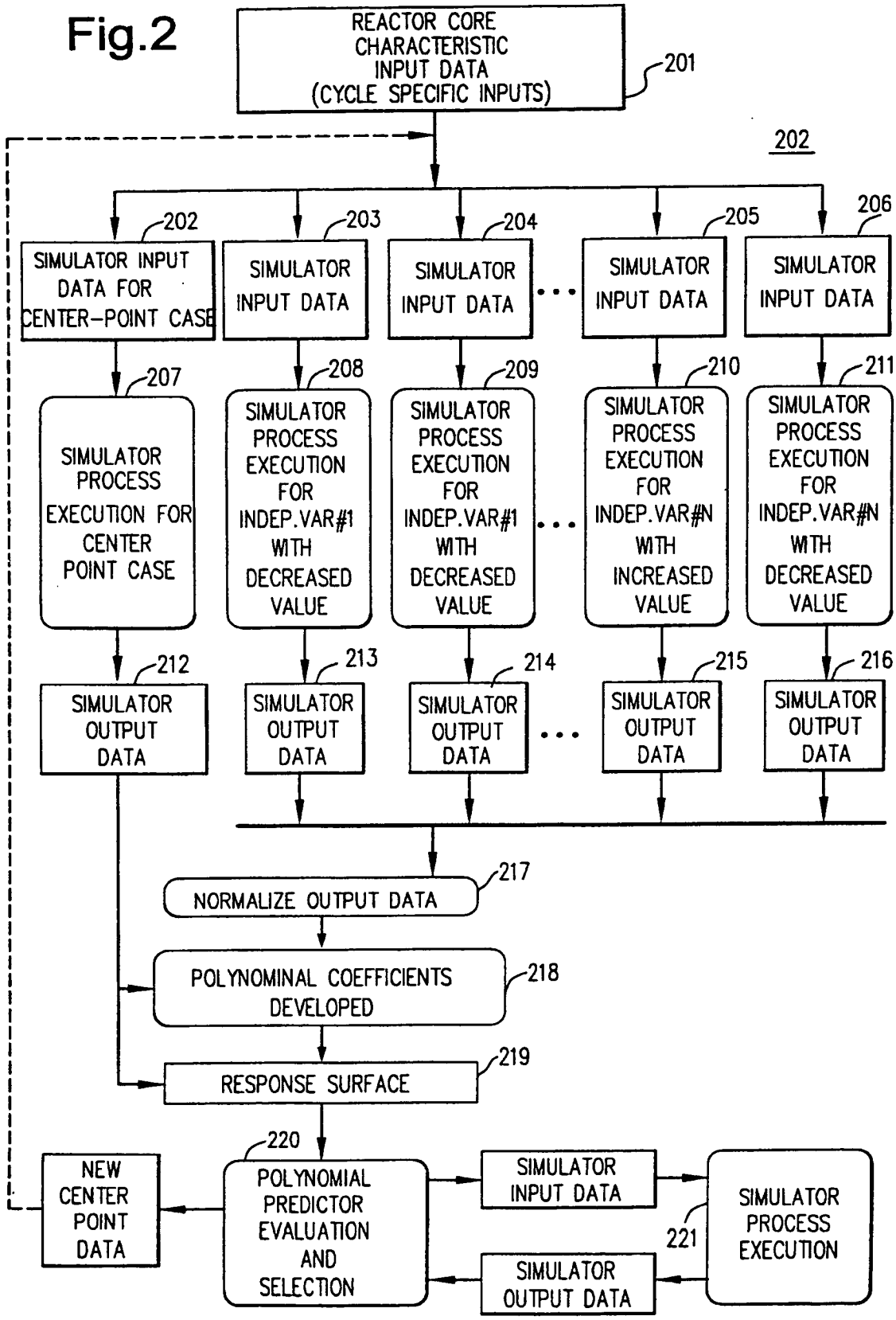

10
12
MEMORY
11
CPU
10
12
MEMORY
11
CPU
10
12
MEMORY
11
CPU
15
20
INTERNET OR
OTHER COMMUNICATIONS
NETWORK
21
REMOTE COMPUTER
LAN

Fig.1B

Fig.2


REACTOR CORE CHARACTERISTIC INPUT DATA (CYCLE SPECIFIC INPUTS)
201
202
202
SIMULATOR INPUT DATA FOR CENTER-POINT CASE
203
SIMULATOR INPUT DATA
204
SIMULATOR INPUT DATA
205
SIMULATOR INPUT DATA
206
SIMULATOR INPUT DATA
207
SIMULATOR PROCESS EXECUTION FOR CENTER POINT CASE
208
SIMULATOR PROCESS EXECUTION FOR INDEP.VAR#1 WITH DECREASED VALUE
209
SIMULATOR PROCESS EXECUTION FOR INDEP.VAR#1 WITH DECREASED VALUE
210
SIMULATOR PROCESS EXECUTION FOR INDEP.VAR#N WITH INCREASED VALUE
211
SIMULATOR PROCESS EXECUTION FOR INDEP.VAR#N WITH DECREASED VALUE
212
SIMULATOR OUTPUT DATA
213
SIMULATOR OUTPUT DATA
214
SIMULATOR OUTPUT DATA
215
SIMULATOR OUTPUT DATA
216
SIMULATOR OUTPUT DATA
217
NORMALIZE OUTPUT DATA
218
POLYNOMINAL COEFFICIENTS DEVELOPED
219
RESPONSE SURFACE
220
NEW CENTER POINT DATA
POLYNOMIAL PREDICTOR EVALUATION AND SELECTION
SIMULATOR INPUT DATA
SIMULATOR OUTPUT DATA
221
SIMULATOR PROCESS EXECUTION

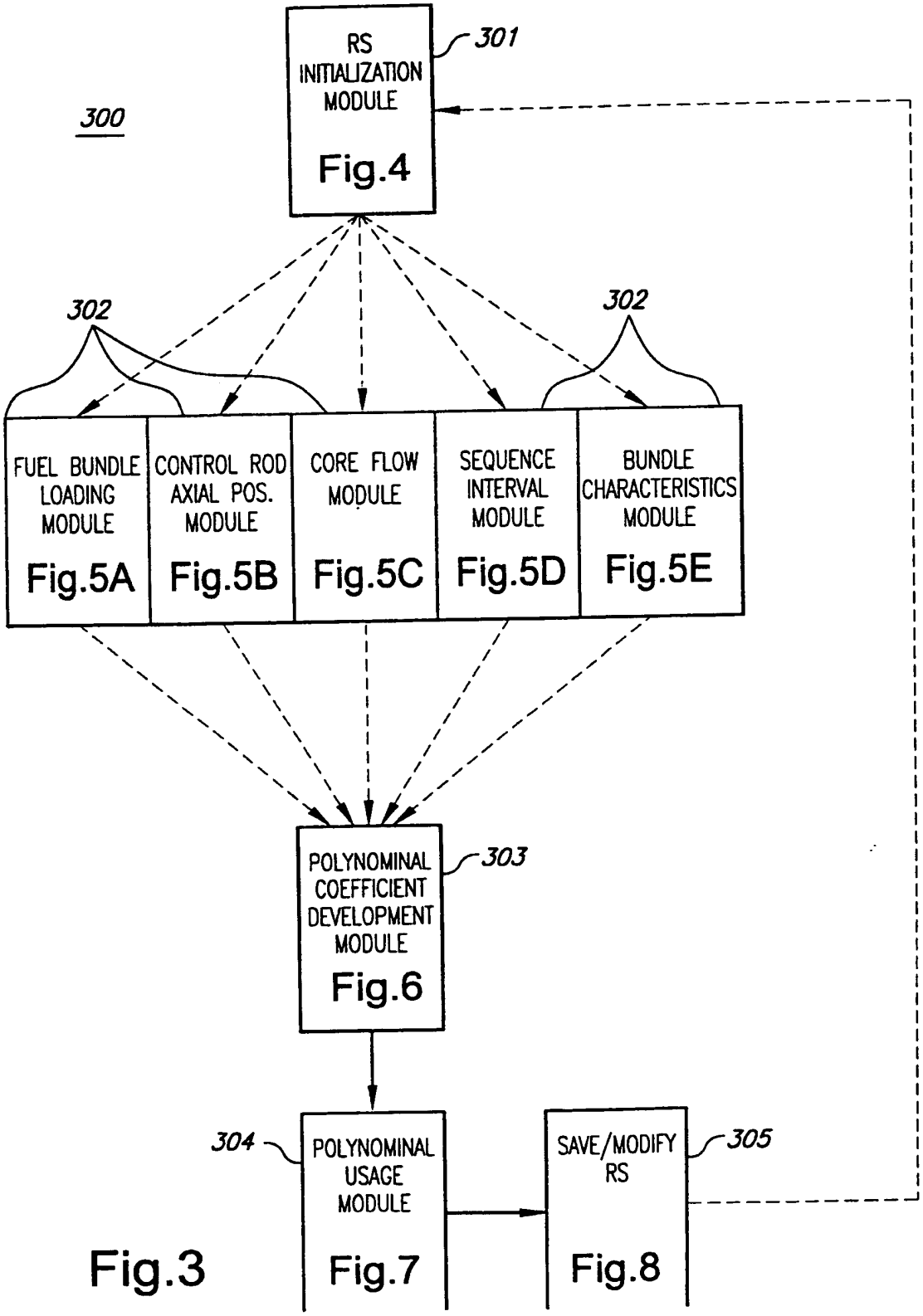

300
RS INITIALIZATION MODULE
Fig.4
301
302
302
FUEL BUNDLE LOADING MODULE
Fig.5A
CONTROL ROD AXIAL POS. MODULE
Fig.5B
CORE FLOW MODULE
Fig.5C
SEQUENCE INTERVAL MODULE
Fig.5D
BUNDLE CHARACTERISTICS MODULE
Fig.5E
POLYNOMINAL COEFFICIENT DEVELOPMENT MODULE
Fig.6
303
304
POLYNOMINAL USAGE MODULE
Fig.7
SAVE/MODIFY RS
Fig.8
305

Fig.3

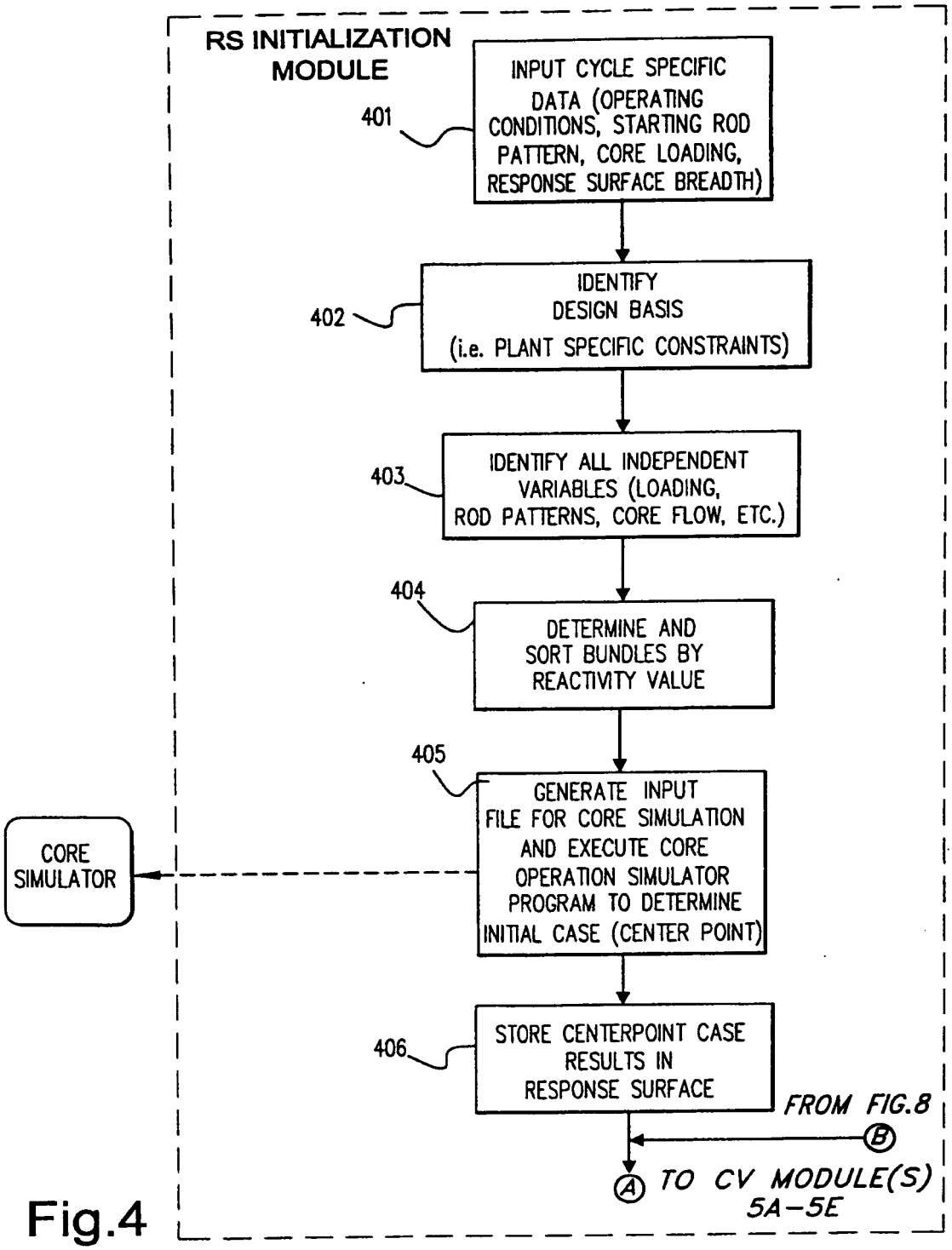

RS INITIALIZATION MODULE
401
INPUT CYCLE SPECIFIC DATA (OPERATING CONDITIONS, STARTING ROD PATTERN, CORE LOADING, RESPONSE SURFACE BREADTH)
402
IDENTIFY DESIGN BASIS (i.e. PLANT SPECIFIC CONSTRAINTS)
403
IDENTIFY ALL INDEPENDENT VARIABLES (LOADING, ROD PATTERNS, CORE FLOW, ETC.)
404
DETERMINE AND SORT BUNDLES BY REACTIVITY VALUE
405
GENERATE INPUT FILE FOR CORE SIMULATION AND EXECUTE CORE OPERATION SIMULATOR PROGRAM TO DETERMINE INITIAL CASE (CENTER POINT)
CORE SIMULATOR
406
STORE CENTERPOINT CASE RESULTS IN RESPONSE SURFACE
FROM FIG.8
B
A
TO CV MODULE(S) 5A-5E

Fig.4

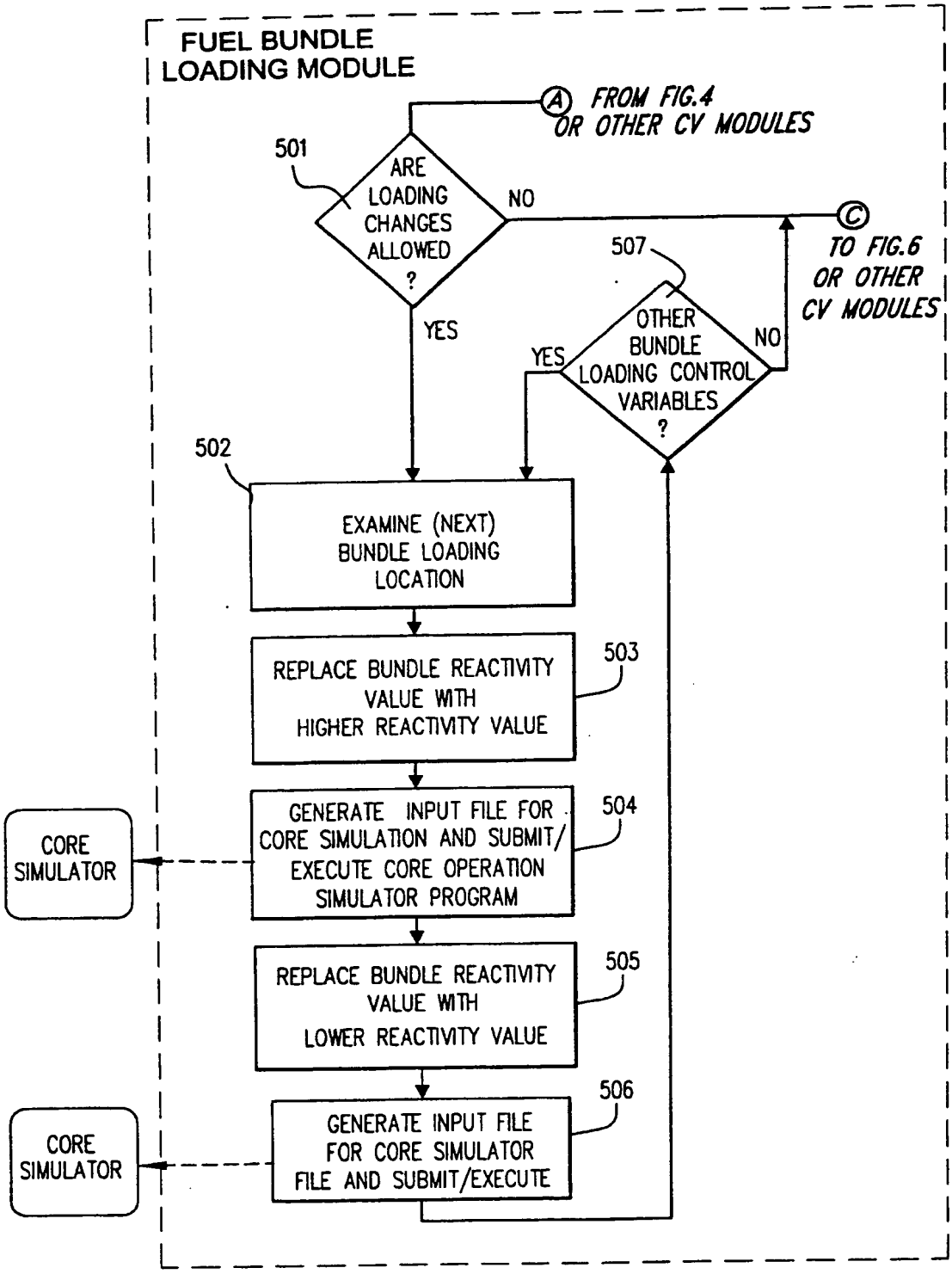

FUEL BUNDLE LOADING MODULE
A
FROM FIG.4 OR OTHER CV MODULES
501
ARE LOADING CHANGES ALLOWED ?
NO
C
TO FIG.6 OR OTHER CV MODULES
YES
507
OTHER BUNDLE LOADING CONTROL VARIABLES ?
YES
NO
502
EXAMINE (NEXT) BUNDLE LOADING LOCATION
REPLACE BUNDLE REACTIVITY VALUE WITH HIGHER REACTIVITY VALUE
503
CORE SIMULATOR
GENERATE INPUT FILE FOR CORE SIMULATION AND SUBMIT/ EXECUTE CORE OPERATION SIMULATOR PROGRAM
504
REPLACE BUNDLE REACTIVITY VALUE WITH LOWER REACTIVITY VALUE
505
CORE SIMULATOR
GENERATE INPUT FILE FOR CORE SIMULATOR FILE AND SUBMIT/EXECUTE
506

Fig.5A

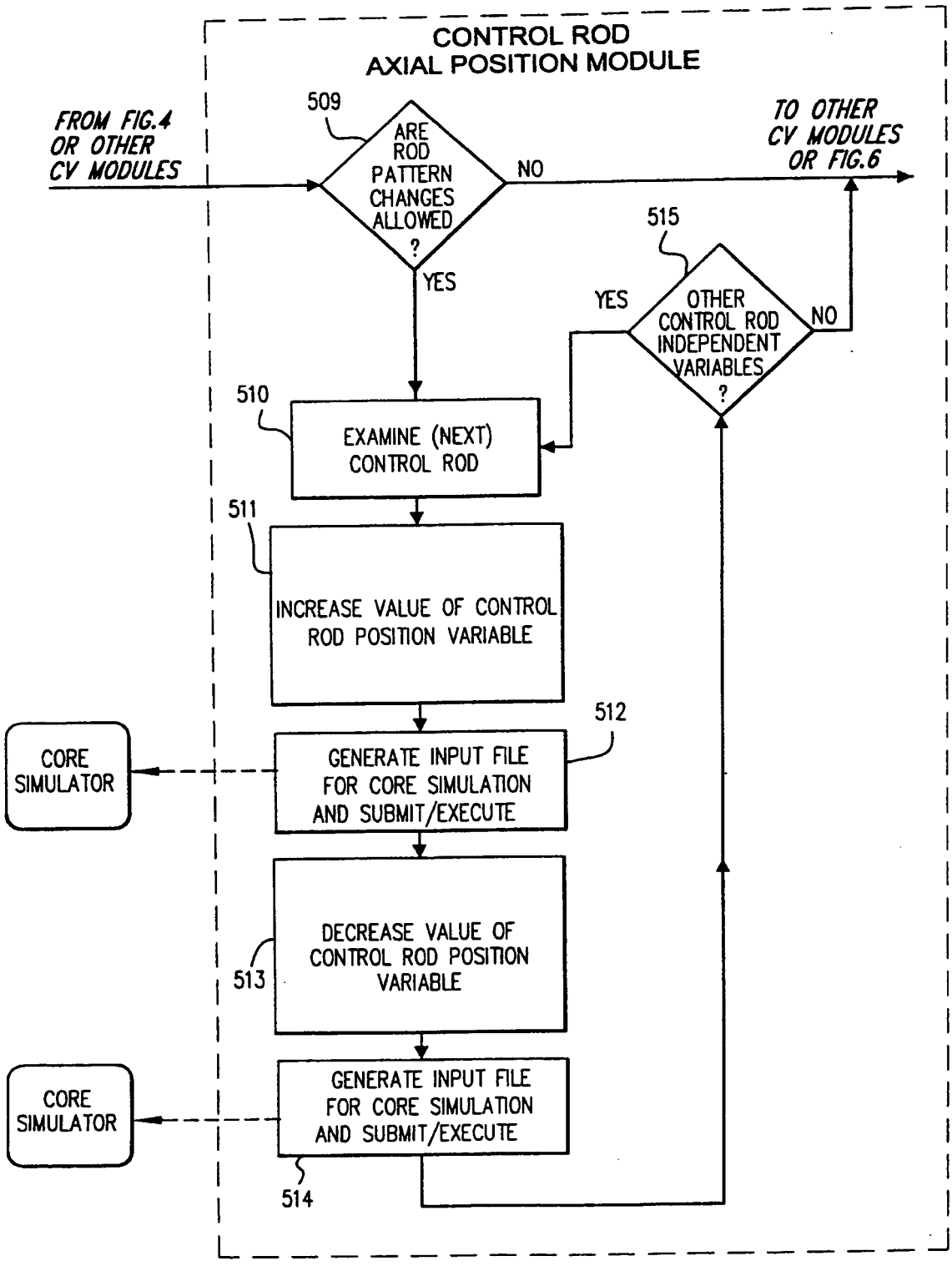

CONTROL ROD
AXIAL POSITION MODULE
FROM FIG.4
OR OTHER
CV MODULES
509
ARE
ROD
PATTERN
CHANGES
ALLOWED
?
NO
TO OTHER
CV MODULES
OR FIG.6
YES
515
YES
OTHER
CONTROL ROD
INDEPENDENT
VARIABLES
?
NO
510
EXAMINE (NEXT)
CONTROL ROD
511
INCREASE VALUE OF CONTROL
ROD POSITION VARIABLE
512
CORE
SIMULATOR
GENERATE INPUT FILE
FOR CORE SIMULATION
AND SUBMIT/EXECUTE
DECREASE VALUE OF
CONTROL ROD POSITION
VARIABLE
513
CORE
SIMULATOR
GENERATE INPUT FILE
FOR CORE SIMULATION
AND SUBMIT/EXECUTE
514

Fig.5B

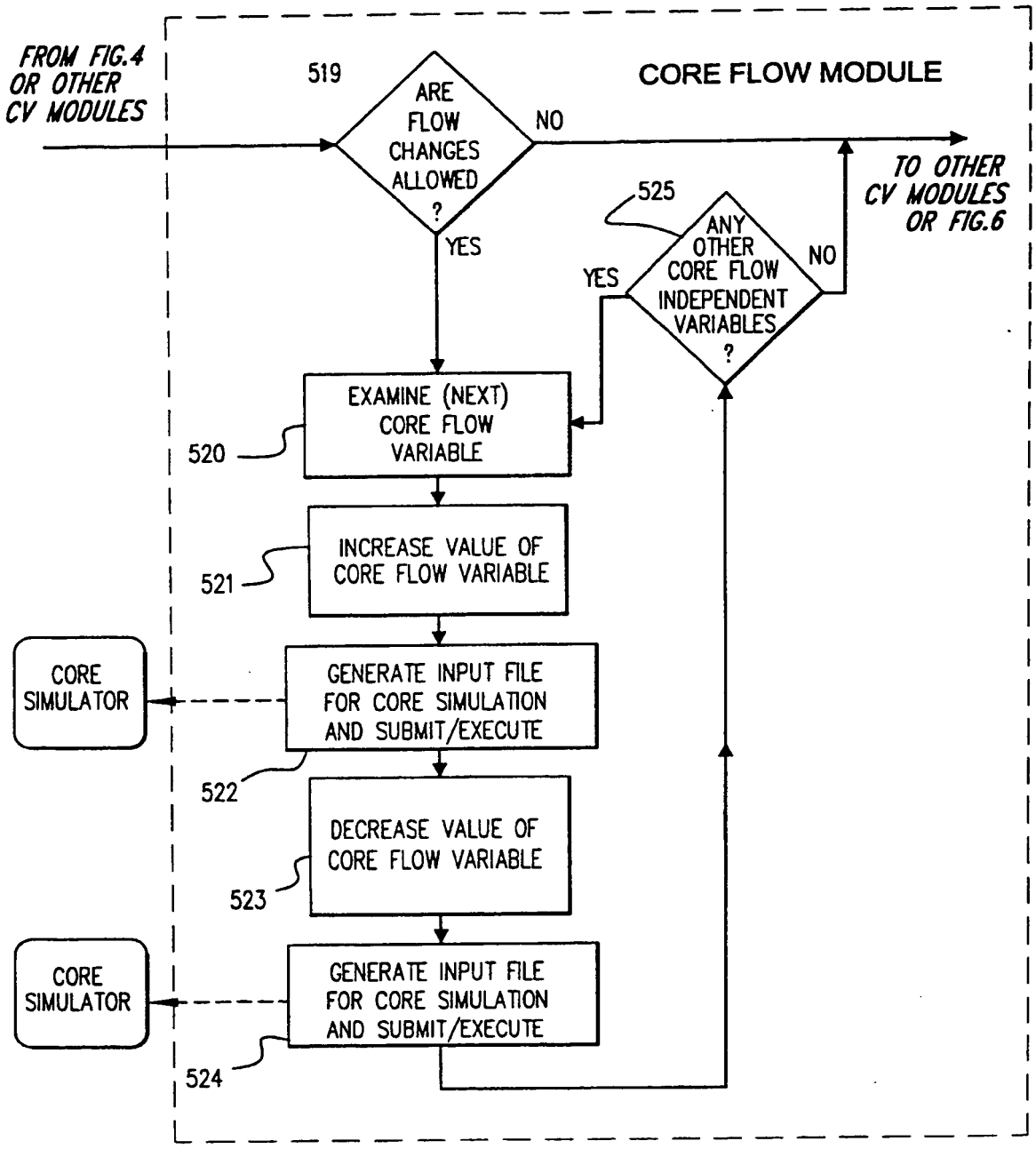

FROM FIG.4 OR OTHER CV MODULES
519
ARE FLOW CHANGES ALLOWED ?
NO
YES
CORE FLOW MODULE
TO OTHER CV MODULES OR FIG.6
525
ANY OTHER CORE FLOW INDEPENDENT VARIABLES ?
YES
NO
EXAMINE (NEXT) CORE FLOW VARIABLE
520
INCREASE VALUE OF CORE FLOW VARIABLE
521
CORE SIMULATOR
GENERATE INPUT FILE FOR CORE SIMULATION AND SUBMIT/EXECUTE
522
DECREASE VALUE OF CORE FLOW VARIABLE
523
CORE SIMULATOR
GENERATE INPUT FILE FOR CORE SIMULATION AND SUBMIT/EXECUTE
524

Fig.5C

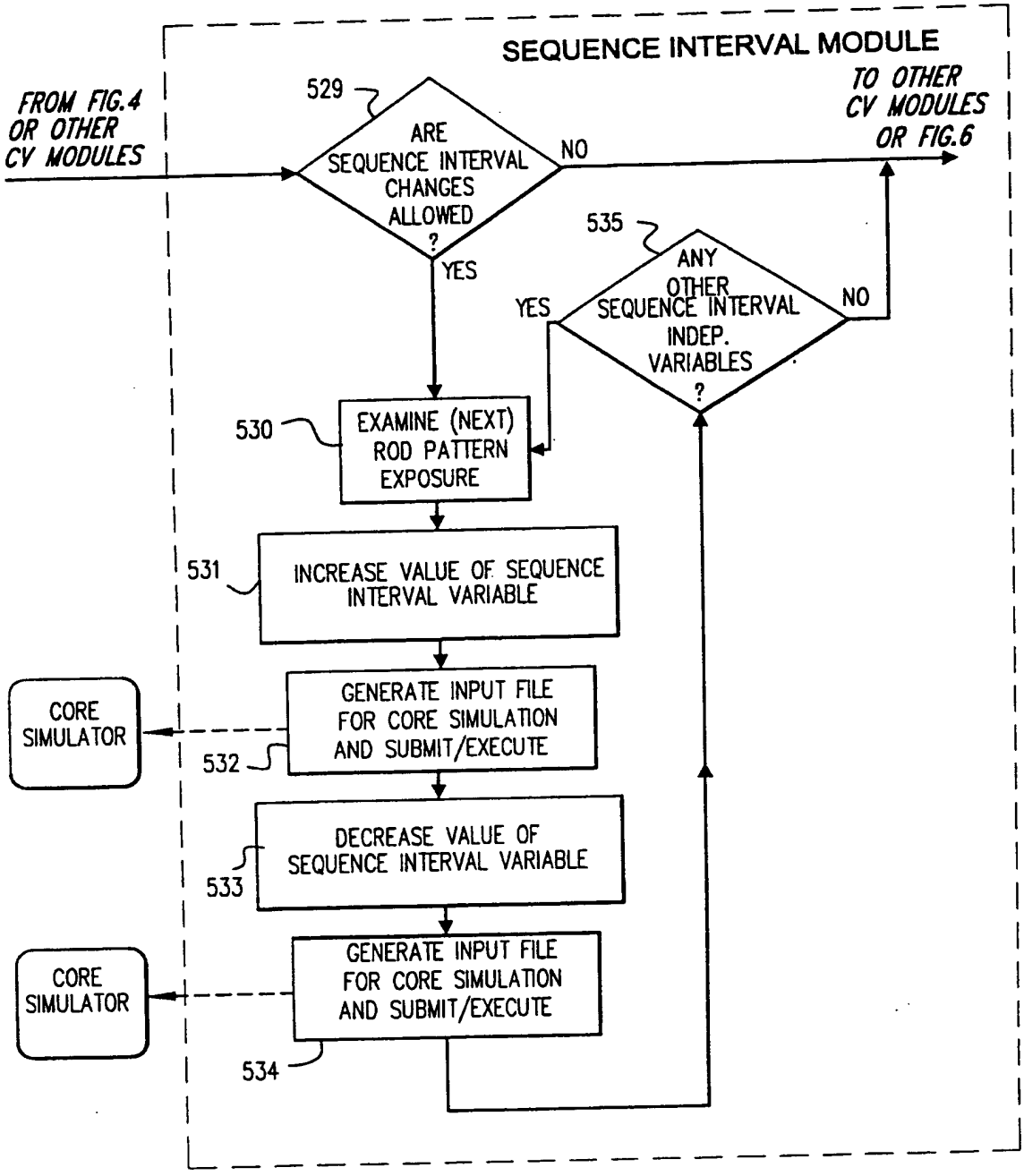

SEQUENCE INTERVAL MODULE
FROM FIG.4 OR OTHER CV MODULES
529
ARE SEQUENCE INTERVAL CHANGES ALLOWED ?
NO
TO OTHER CV MODULES OR FIG.6
YES
535
ANY OTHER SEQUENCE INTERVAL INDEP. VARIABLES ?
YES
NO
530
EXAMINE (NEXT) ROD PATTERN EXPOSURE
531
INCREASE VALUE OF SEQUENCE INTERVAL VARIABLE
CORE SIMULATOR
GENERATE INPUT FILE FOR CORE SIMULATION AND SUBMIT/EXECUTE
532
533
DECREASE VALUE OF SEQUENCE INTERVAL VARIABLE
CORE SIMULATOR
GENERATE INPUT FILE FOR CORE SIMULATION AND SUBMIT/EXECUTE
534

Fig.5D

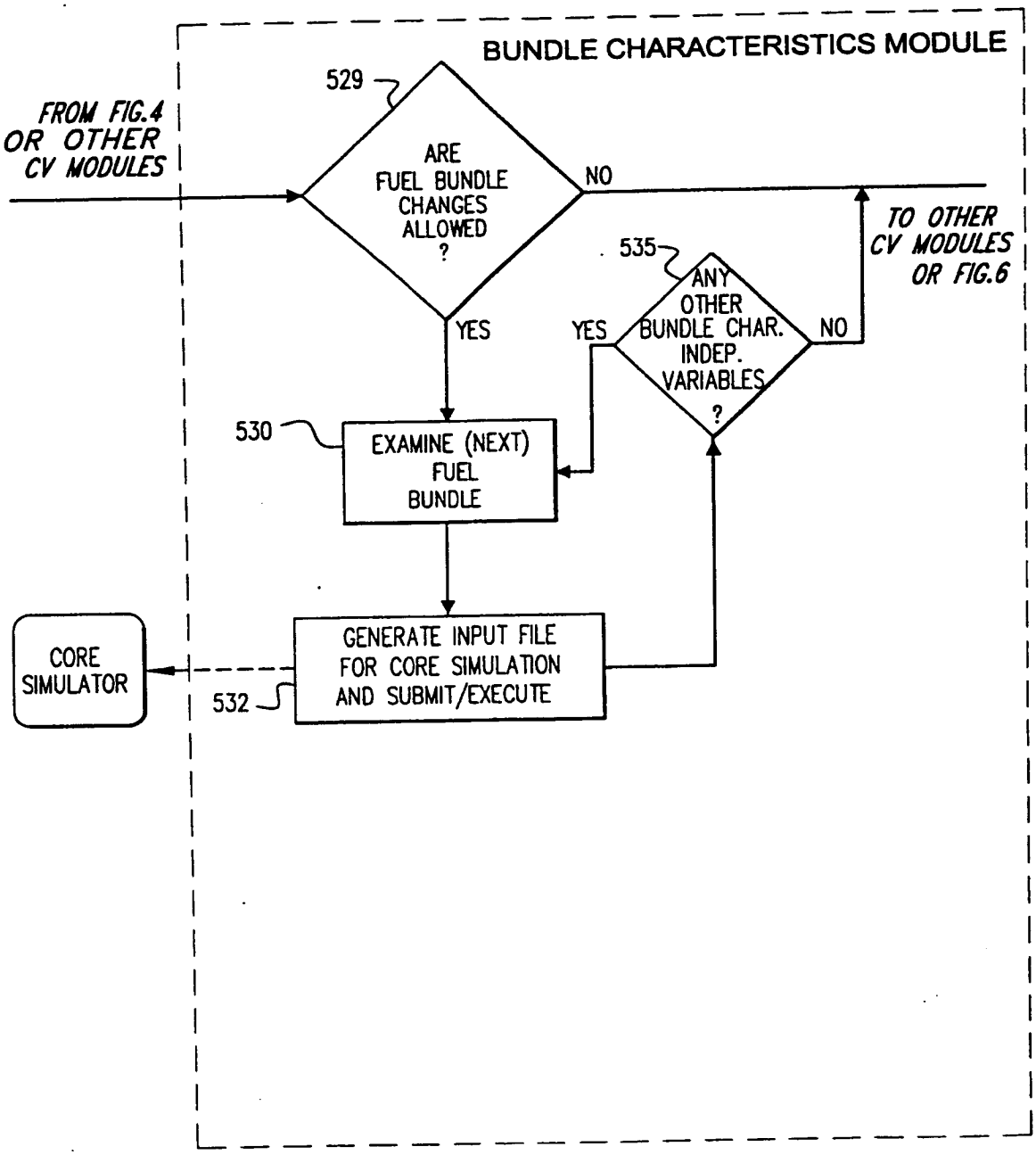

BUNDLE CHARACTERISTICS MODULE
FROM FIG.4 OR OTHER CV MODULES
529
ARE FUEL BUNDLE CHANGES ALLOWED ?
NO
TO OTHER CV MODULES OR FIG.6
535
ANY OTHER BUNDLE CHAR. INDEP. VARIABLES ?
YES
YES
NO
530
EXAMINE (NEXT) FUEL BUNDLE
GENERATE INPUT FILE FOR CORE SIMULATION AND SUBMIT/EXECUTE
532
CORE SIMULATOR

Fig.5E

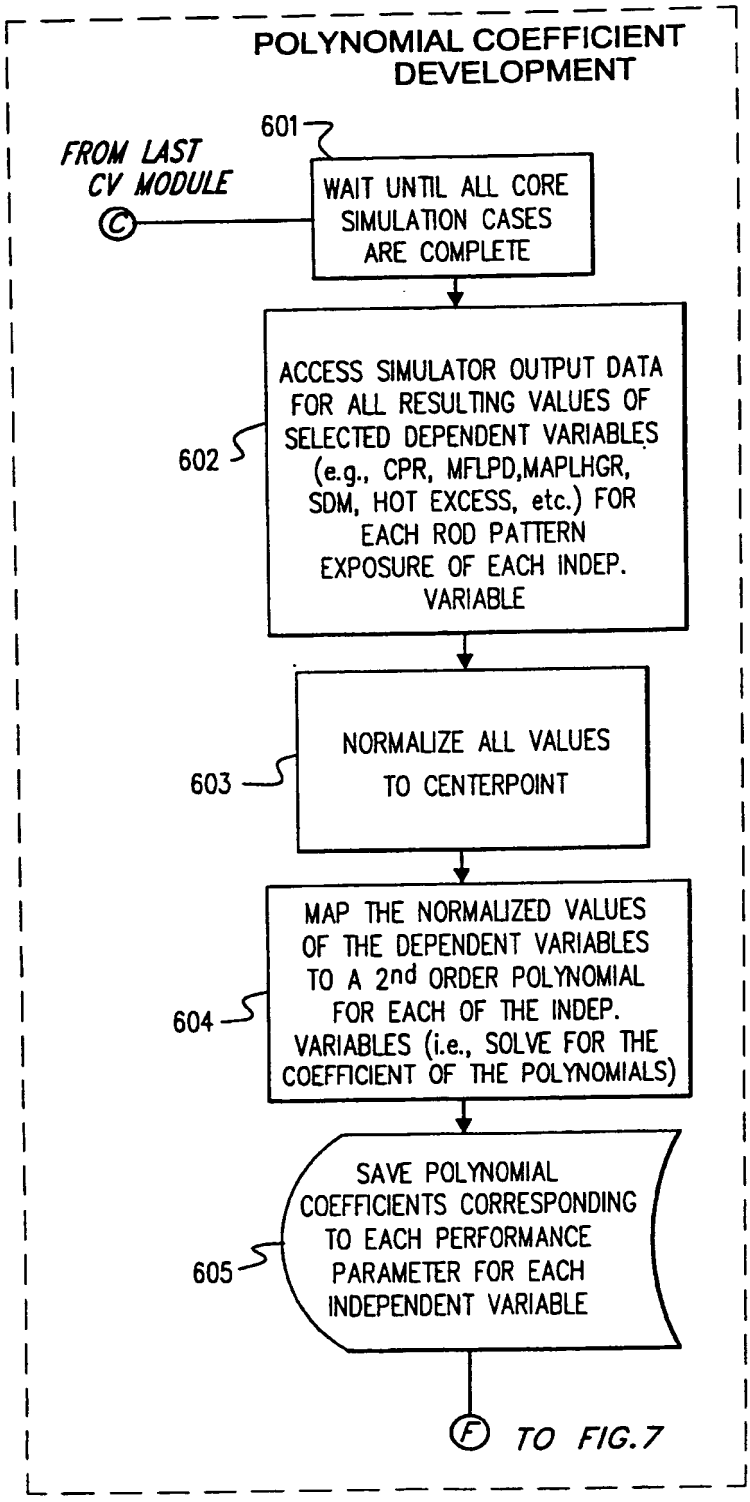

POLYNOMIAL COEFFICIENT DEVELOPMENT
601
FROM LAST CV MODULE
C
WAIT UNTIL ALL CORE SIMULATION CASES ARE COMPLETE
602
ACCESS SIMULATOR OUTPUT DATA FOR ALL RESULTING VALUES OF SELECTED DEPENDENT VARIABLES (e.g., CPR, MFLPD,MAPLHGR, SDM, HOT EXCESS, etc.) FOR EACH ROD PATTERN EXPOSURE OF EACH INDEP. VARIABLE
603
NORMALIZE ALL VALUES TO CENTERPOINT
604
MAP THE NORMALIZED VALUES OF THE DEPENDENT VARIABLES TO A 2nd ORDER POLYNOMIAL FOR EACH OF THE INDEP. VARIABLES (i.e., SOLVE FOR THE COEFFICIENT OF THE POLYNOMIALS)
605
SAVE POLYNOMIAL COEFFICIENTS CORRESPONDING TO EACH PERFORMANCE PARAMETER FOR EACH INDEPENDENT VARIABLE
F
TO FIG.7

Fig.6

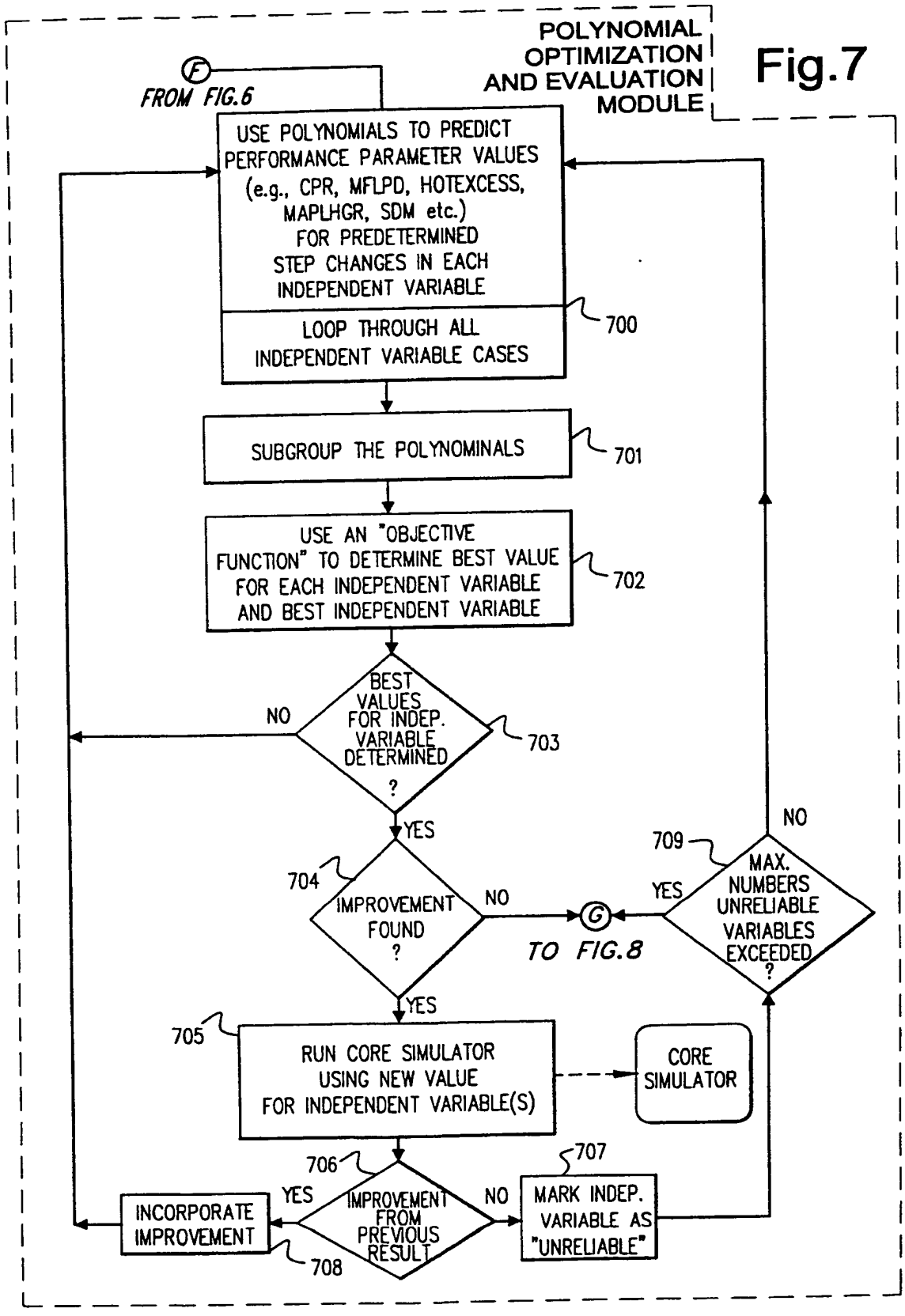

POLYNOMIAL OPTIMIZATION AND EVALUATION MODULE
FROM FIG.6
USE POLYNOMIALS TO PREDICT PERFORMANCE PARAMETER VALUES (e.g., CPR, MFLPD, HOTEXCESS, MAPLHGR, SDM etc.) FOR PREDETERMINED STEP CHANGES IN EACH INDEPENDENT VARIABLE
LOOP THROUGH ALL INDEPENDENT VARIABLE CASES
700
SUBGROUP THE POLYNOMINALS
701
USE AN "OBJECTIVE FUNCTION" TO DETERMINE BEST VALUE FOR EACH INDEPENDENT VARIABLE AND BEST INDEPENDENT VARIABLE
702
BEST VALUES FOR INDEP. VARIABLE DETERMINED ?
703
NO
YES
704
IMPROVEMENT FOUND ?
NO
TO FIG.8
YES
709
MAX. NUMBERS UNRELIABLE VARIABLES EXCEEDED ?
YES
NO
705
RUN CORE SIMULATOR USING NEW VALUE FOR INDEPENDENT VARIABLE(S)
CORE SIMULATOR
706
IMPROVEMENT FROM PREVIOUS RESULT
YES
NO
707
MARK INDEP. VARIABLE AS "UNRELIABLE"
INCORPORATE IMPROVEMENT
708

Fig.7

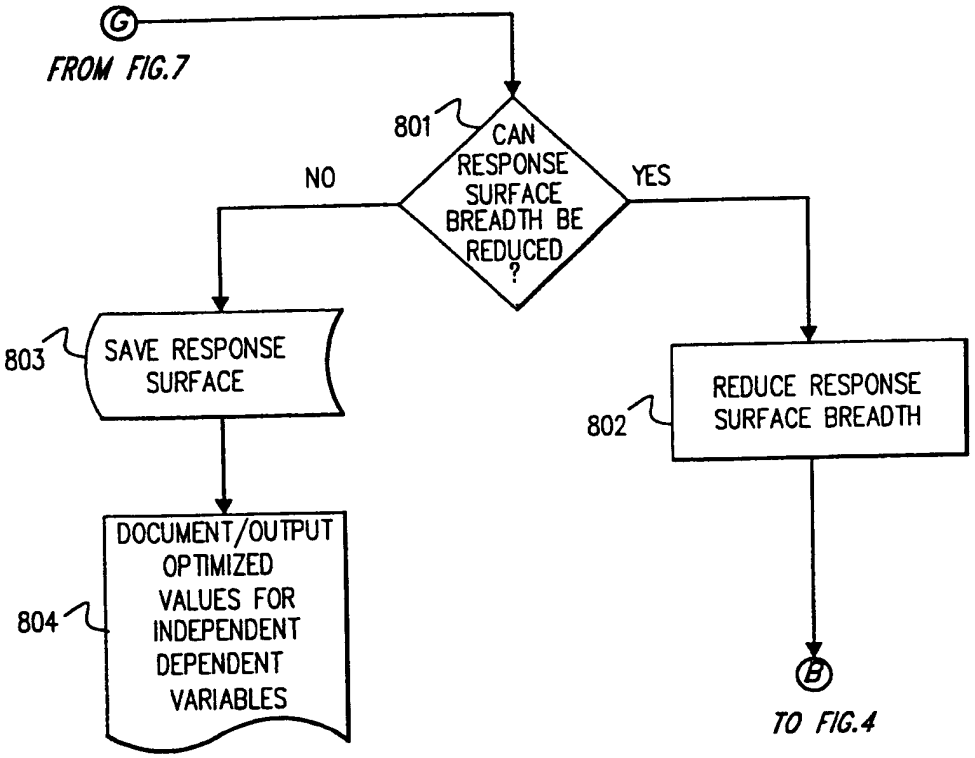

G
FROM FIG.7
801
CAN RESPONSE SURFACE BREADTH BE REDUCED ?
NO
YES
803
SAVE RESPONSE SURFACE
802
REDUCE RESPONSE SURFACE BREADTH
DOCUMENT/OUTPUT OPTIMIZED VALUES FOR INDEPENDENT DEPENDENT VARIABLES
804
B
TO FIG.4

Fig.8

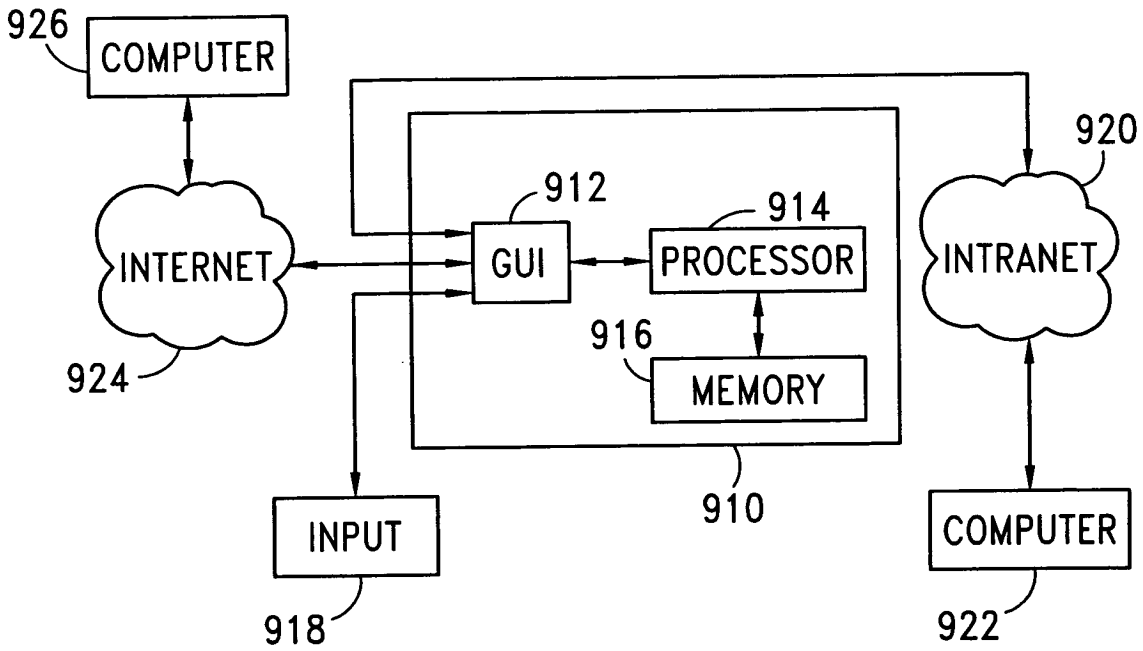

926
COMPUTER
INTERNET
924
912
914
GUI
PROCESSOR
916
MEMORY
910
920
INTRANET
INPUT
918
COMPUTER
922

Fig. 9

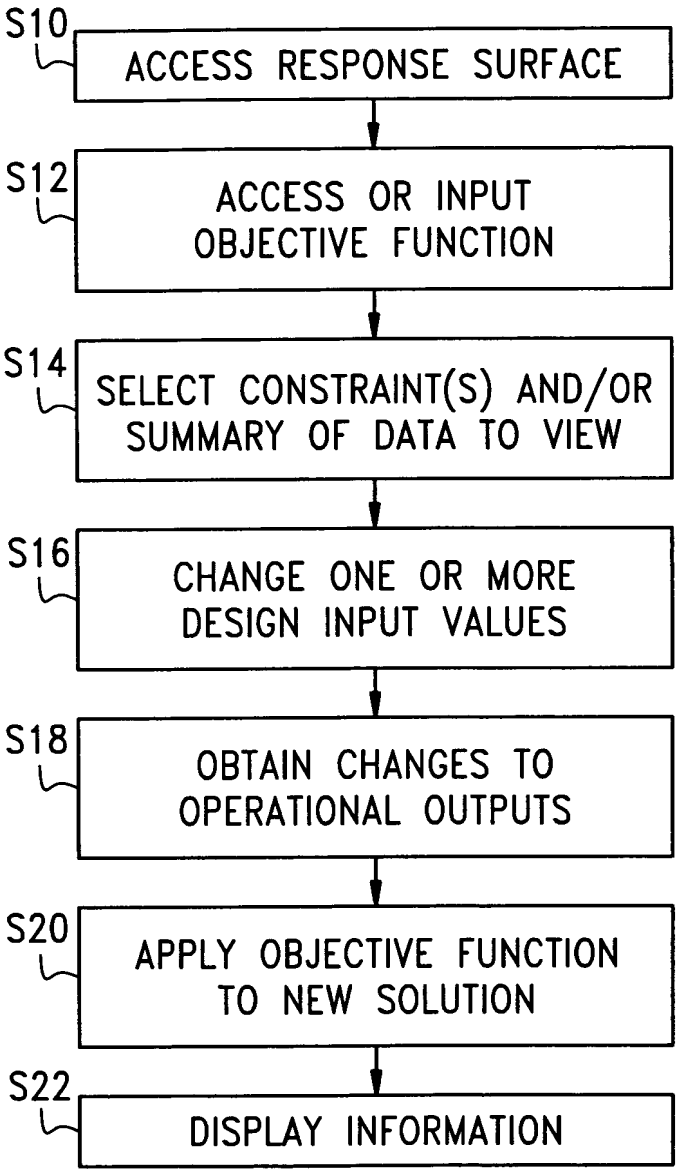

S10
ACCESS RESPONSE SURFACE
S12
ACCESS OR INPUT OBJECTIVE FUNCTION
S14
SELECT CONSTRAINT(S) AND/OR SUMMARY OF DATA TO VIEW
S16
CHANGE ONE OR MORE DESIGN INPUT VALUES
S18
OBTAIN CHANGES TO OPERATIONAL OUTPUTS
S20
APPLY OBJECTIVE FUNCTION TO NEW SOLUTION
S22
DISPLAY INFORMATION

Fig. 10

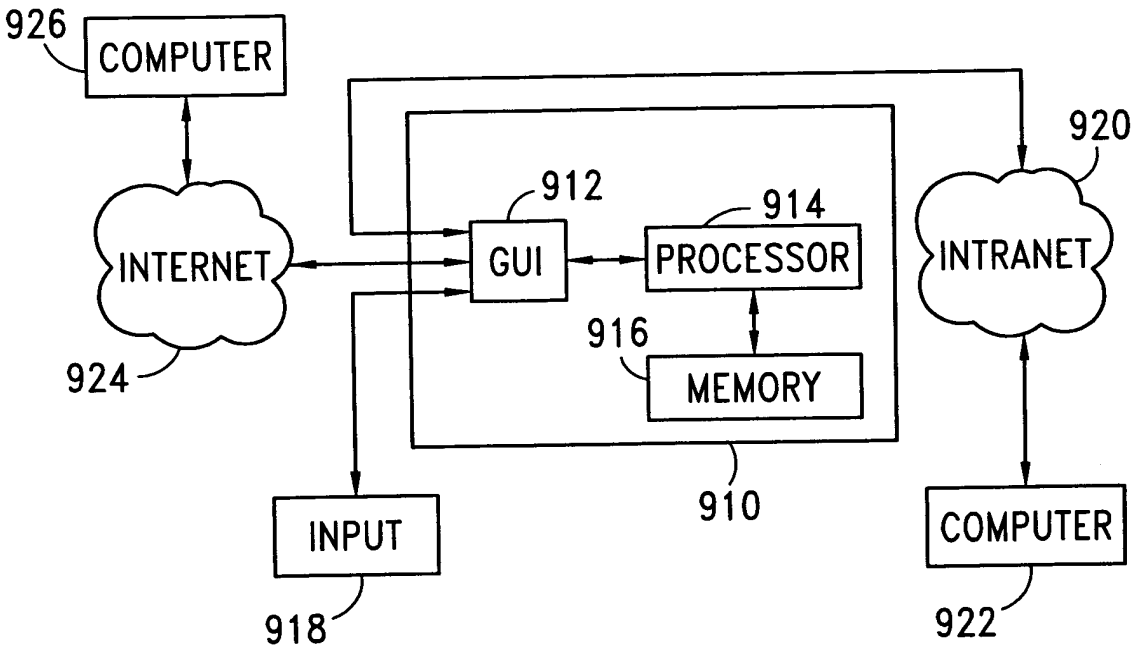

926
COMPUTER
INTERNET
924
912
914
GUI
PROCESSOR
916
MEMORY
910
920
INTRANET
INPUT
918
COMPUTER
922

Fig. 9

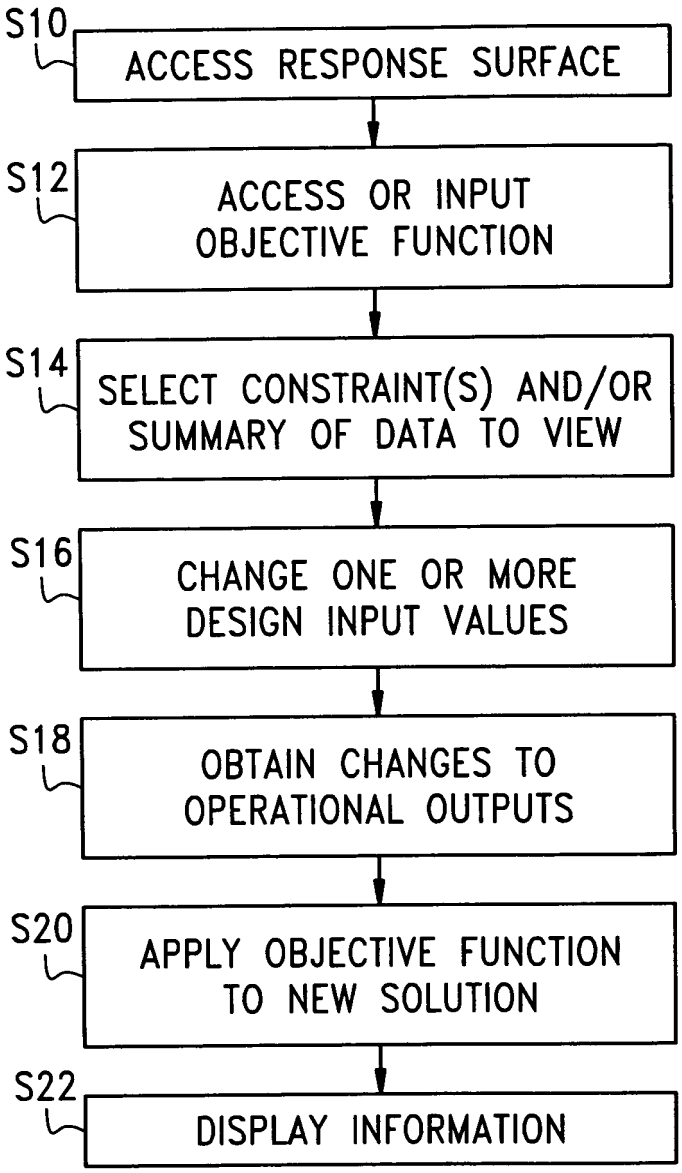

S10
ACCESS RESPONSE SURFACE
S12
ACCESS OR INPUT OBJECTIVE FUNCTION
S14
SELECT CONSTRAINT(S) AND/OR SUMMARY OF DATA TO VIEW
S16
CHANGE ONE OR MORE DESIGN INPUT VALUES
S18
OBTAIN CHANGES TO OPERATIONAL OUTPUTS
S20
APPLY OBJECTIVE FUNCTION TO NEW SOLUTION
S22
DISPLAY INFORMATION

Fig. 10